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Salt-tolerant trees usable for Central European cities – A review

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Abstract

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The present text is focused on an actual problem of planting of inappropriate tree taxa in many cities. It explains the causes of contaminated soils by winter salt management and principles of the toxic effect on plants. The paper summarizes the problem and brings solution. Town places with salt-contaminated soil should not be fitted with: spruce (*Picea*), pine (*Pinus*), linden (*Tilia*) and maples (*Acer*). On the other hand, resistant species are: ash (*Fraxinus*), poplar (*Populus*), willow (*Salix*), silverberry (*Eleagnus*), black locust (*Robinia*). Both lists of sensitive and salt-tolerant tree species have been presented. Salt-tolerant tree should be preferred before all the others species.

Keywords: urban area; management; salinity; town; landscape planning

People migrating from villages to towns and villages being changed into towns are significant trends of the last decades. Almost 75% of Europeans live in urban areas, and the number is expected to rise to 80% by 2020. The quality of life and health of citizens is dependent on urban environment, and social, economic and cultural relationships (EEA 2010). Green places in town play an important role (Jebavý 2007; Mareček 2007). A contact with nature and an access to safe green places enrich mental and social aspects of urban life. People living in natural environment are more satisfied with the quality of their lives (Maas et al. 2006; Croucher et al. 2007).

In urban areas, demands on energy and transport are growing, and so is the amount of contaminants and pollutants in air. Soil contamination by salt is characteristic for many places in the big towns (Cekstere, Osvalde 2015). The structure of soil changes – it is too dense, it does not contain enough air, and the movement of water is reduced (Spellerberg 2002).

Winter management of roads, applying defrosting materials, is a significant factor influencing chemical composition of urban soil (Forman 2002; Šerá 2008). Sodium chloride (NaCl) and slightly toxic calcium chloride ($CaCl_2$) are commonly used in Central Europe (Czerniawska-Kusza et al. 2004). Other possibilities are magnesium chloride ($MgCl_2$), calcium magnesium acetate (CMA), potassium format (KFo), technical carbamide ($CO(NH_2)_2$), alcohols or glycols (Amrhein, Strong 1990; Spellerberg 1998; Forman 2002; Hanslin 2011; Goodrich, Jacobi 2012). The cold-season in the central Europe is connected with continental climate. Differences in atmospheric gradients during winter are changed (Hernandez-Almeida 2015). Both the greater weather fluctuations and variability in the amount of salt used in winter maintenance should be assumed.

Planning new planting and permanent management of current greenery in towns should be in ac-

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cordance with sustainable development of towns (Sera 2013). Soil along roads treated with salt is contaminated with defrosting substances (usually NaCl), which are toxic for many plant and tree species. The most effective precaution is prevention. This article names tree species that are not suitable to be planted near salt-treated roads, and it also brings a list of species that are salt-tolerant, thus highly recommendable for urban planting.

Symptoms of woody plant damages

Salt maintenance in European towns started in the 1970s, and that was the beginning of mass dying of woody plants in urban areas (Franěk 1993). It is presented that soil along roads contaminated by salt is in stripes from 7 to 10 m wide (Marosz 2011), but it has also been proved in much further distances. Repeated applications of salt result in alcalisation of soil, and moreover, Na^+ and Cl^- do not wash out even after frequent rains (Franěk 1993). The first effect of salt is in salt spraying on aboveground body of plant, the second is in contact between contaminated soil and underground part of plant. The types of salt/plant contacts may vary in their response (Paludan-Muller 2002).

Ions of Na and Cl in high soil concentration are harmful or toxic for plants. Increased concentration in cell can inhibit membrane functions, induce ion deficiency, decrease chlorophyll concentration and the activity of some enzymes and decrease concentrations of some proteins, disturbing various metabolic processes (Bryson, Barker 2002; Czerniawska-Kusza et al. 2004). There is a positive linear dependency between a plant damage and a content of chlorine in its assimilation organs (Goodrich et al. 2009; Goodrich, Jacobi 2012).

The indications of plant damage are the following: change of leaf colour (autumn colours, yellow needles) and wilting (Czerniawska-Kusza et al. 2004; Dmuchowski et al. 2011). Necrosis usually progrades from the top to the basis of the leaf and spreads on (Brod, Preuse 1975). Other symptoms are premature leaf and needle fall off, bud and shoot necrosis, wilting. At the beginning of the process, trees do not show symptoms of permanent damage – it becomes obvious after several seasons.

Long-time stress caused by salt results in slow growth. That can be proved by annual ring growth (Meyer, Hoster 1980). Extensive salt management and long-time stress probably do not reduce flowering and growth of generative organs. That was observed with herbs (Šerá et al. 2011) and it is probably a general protective reaction of plants in difficult conditions. Nevertheless, a long salt stress causes the death of trees.

Table 1. List of sensitive woody species that are not tolerant to saline soil and to contact with salt

Tree	Soldini et al. (1974)	Suchara (1982)	Franěk (1993)
Acer platanoides	yes	yes	–
Acer pseudoplatanus	yes	yes	–
Aesculus hippocastanum	–	yes	–
Alnus incana	–	–	yes
Berberis vulgaris	–	–	yes
Carpinus betulus	yes	–	yes
Cornus mas	–	–	yes
Cornus sanguinea	–	–	yes
Coryllus avellana	yes	–	yes
Cotoneaster horizontalis	–	–	yes
Fagus sylvatica	yes	–	yes
Ligustrum vulgaris	yes	–	–
Picea abies	–	–	yes
Pinus sylvestris	–	–	yes
Prunus avium	yes	–	yes
Pyracantha coccinea	–	–	yes
Quercus petraea	–	–	yes
Rhamnus cathartica	–	–	yes
Rosa canina	yes	–	yes
Rosa rubiginosa	–	–	yes
Rubus fruticosus	yes	–	–
Salix purpurea		–	yes
Sambucus nigra	yes	–	–
Sambucus racemosa	yes	–	–
Sorbus aria	–	–	yes
Sorbus aucuparia	–	–	yes
Taxus baccata	–	–	yes
Tilia argentea	–	yes	–
Tilia cordata	–	yes	–
Tilia platyphyllos	–	yes	–
Tilia sp.	yes	–	–
Ulmus carpinifolia	yes	–	–
Ulmus glabra	yes	–	–

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Table 2. List of salt tolerant woody species

Trees	Meyer (1982)	Suchara (1986)	Van den Berk (2002)
Acer campestre	–	orange	green
Acer platanoides	yellow	yellow	–
Acer pseudoplatanus	yellow	yellow	–
Acer tataricum	–	–	green
Aesculus carnea	yellow	–	–
Aesculus hippocastanum	yellow	–	–
Ailantus altissima	orange	–	–
Alnus cordata	red	–	green
Alnus glutinosa	–	yellow	green
Alnus sp.	–	–	green (1)
Amelanchier sp.	–	–	green (2)
Betula pendula	red	–	–
Caragana arborescens	orange	red	–
Colutea arborescens	orange	–	–
Coryllus colurna	red	–	–
Eleagnus angustifolia	orange	orange	green
Fraxinus excelsior	orange	orange	green
Fraxinus sp.	–	–	green (3)
Gleditsia triacanthos	orange	–	green
Hippophae rhamnoides	orange	–	–
Hippophae salicifolia	–	–	green
Juniperus sp.	–	yellow	–
Laburnum sp.	–	–	green (4)
Ligustrum vulgaris	red	–	–
Lonicera sp.	–	orange	–
Lonicera tatarica	yellow	–	–
Lonicera xylosteum	yellow	–	–
Lycium barbatum	orange	–	–
Picea pungens	–	orange	–
Picea mugo	–	red	–
Pinus nigra	–	orange	–
Platanus sp.	red	–	green (5)
Populus alba	red	red	green
Populus balsamifera	red	–	–
Populus × *beroninensis*	red	–	–
Populus × *canadensis*	–	–	green (6)
Populus × *canescens*	–	–	green
Populus nigra	–	yellow	green
Populus simonii	red	–	green
Populus tremula	–	–	green
Prunus spinosa	–	red	–
Quercus robur	red	–	green
Quercus rubra	–	orange	green
Quercus sp.	–	–	green (7)
Ribes alpinum	yellow	orange	–
Ribes aureum	yellow	–	–
Robinia pseudoacacia	orange	orange	green (8)
Robinia sp.	–	–	green (9)
Rosa rugosa	orange	orange	–
Salix alba	–	yellow	–
Sambucus nigra	red	–	–
Sophora japonica	red	red	green
Sorbus aria	red	–	–
Sorbus aucuparia	–	yellow	–
Sorbus intermedia	red	–	–
Spirea vanhouttei	–	red	–
Symphoricarpos albus	–	red	–
Syringa vulgaris	–	orange	–
Tamarix sp.	orange	–	–
Ulmus glabra	–	yellow	–
Ulmus minor	yellow	–	–
Ulmus pumila	yellow	–	–
Ulmus × *hollandica*	yellow	–	–
Viburnum lantana	–	red	–

Table 2 to be continued

Explanatory notes

yellow	Tolerant to contact with salt
red	Tolerant to saline soil
orange	Tolerant to both saline soil and contact with salt
green	Tolerant to soil, unspecified
(1)	species: *A. incana, A. rubra*
(2)	species: *A. arborea, A. laevis, A. lamarckii*
(3)	species: *F. americana, F. angustifolia, F. biltmoreana, F. ornus, F. pennsylvanica, F. xanthoxyloides*
(4)	species: *L. alpinum, L. anagyroides, L.* × *watereri*
(5)	species: *P.* × *acerifolia, P. occidentalis, P. orientalis*
(6)	cultivars: 'Flevo', 'Marilandica', 'Robusta', 'Serotina'
(7)	species: *Q. acutissima, Q. bicolor, Q. castaneifolia, Q. cerris, Q. coccinea, Q. dentata, Q. ellipsoidalis, Q. frainetto, Q.* × *hispanica, Q. Ilex, Q. imbricaria, Q. ithaburensis, Q. libani, Q. macranthera, Q. palustris, Q. petraea, Q. phellos, Q. pontica, Q. pubescens, Q. pyrenaica, Q. shumardii, Q. suber, Q. turneri, Q. velutina*
(8)	many cultivars
(9)	species: *R.* × *ambigua, R.* × *margaretta, R. viscosa*

Species tolerance of woody plants

There is a various degree of plant tolerance to salt. Depending on tolerance to salt, plants can be divided into four categories (Tsopa 1939 in Waisel 1972). They are (1) obligatory halophytes – plants requiring salinity throughout their life, (2) preferential halophytes – plants show optimum growth in saline habitats, despite their appearance in non-saline habitats, (3) supporting halophytes – non-aggressive plants which are capable of growing in saline, (4) accidental halophytes – plant which grow in marsh saline habitats only accidentally.

The trees originated in central Europe are not halophytes. They can be considered only as for their tolerance to the soil content. Only some tree species tolerate salts, but their optimal development is

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in non-saline habitats. Some tree species are tolerant in soil salinity and some in salt-spray drift (Do-Gyun 2010). Generally, conifers, fruit trees (stone fruits) and young trees are more prone to be damaged by salt than deciduous trees and trees older than 3–5 years (Franěk 1993; El-Siddig, Ludders 1996; Kayama et al. 2003; Goodrich et al. 2009).

Different authors recommend different procedures for particular species, probably depending on their experience connected with specific biotic and abiotic factors. Reactions of woody species depend on other factors – external environmental conditions, age, type of pre-growing etc. The resulting health condition reflects a synergic impact of all factors. For example, if a plant with a high demand of water is planted in a dry place, it will be more sensitive to all stress factors.

The best solution to trees dying due to salt is prevention. That means avoiding planting species with low resistance to salt. In European towns, those are mainly original coniferous species (spruce and pine), linden, some maples and horse chestnut (Soldini 1974; Suchara 1982; Franěk 1993; Kayama et al. 2003; Oleksyn et al. 2007; Hanslin 2011; Marosz 2009, 2011) (Table 1). On the other hand, resistant species which should be planted, are some ash species, poplar and willow (Meyer 1982; Suchara 1986; Van den Berk 2002; Kennedy et al. 2003; Marosz 2009, 2011; Wang et al. 2011). Considering that urban areas are not in the original landscape condition, it is acceptable to introduce new species and cultivars. Extending the list of suitable trees for the city of tolerant exotic species is appropriate (Pejchal 2001). Planes, tamarisks, honey locust and other salt resistant species can be recommended (Table 2). Tree breeding aimed at salt-resistant taxons is another possible direction in prevention (e.g. transgenic hybrid poplars, Su et al. 2011).

Prevention

Reduction of negative impacts of salt on greenery in towns is connected with road maintenance and purposely planned vegetation and its management. This concerns only precautions for current or future planting. The most effective precaution is planting salt-tolerant species (Table 2), and similarly excluding salt-sensitive species (Table 1). In current plantings, these species should be gradually substituted with the resistant ones.

Introducing salt-tolerant taxons without knowing of their other demands, is counter-productive (Pejchal 2001). It is necessary to choose species with respect to climatic and other local conditions (northern hemisphere, country, climatic sub-region).

Other important precautions are pre-growth and subsequent care. For new plantings, it is necessary to pay attention to the minimum distance from the road. The maximum distance should be preferred, above all in relation to salt spray drift. Sand drainage in planting holes is recommendable as it helps conduct chlorides off the roots. Planted trees should be at least 3–5 years old, with well-developed roots, and planting should be done in spring time.

Woody plants face the biggest salt stress immediately after snow melts and soil defrosts, before they start germinating in the spring. Thus a part of urban plant management should be early-spring irrigation which helps conduct away a large amount of ions from soil (particularly Cl^-). Loosening the soil, fertilizing with trace elements and adding humus will help the germinating plant to manage spring stress (El-Siddig, Ludders 1996; Grattan, Grieve 1999; Oleksyn et al. 2007; Marosz 2011). Before a winter season, placing surface mulch will absorb majority of chlorides. Mulch has to be removed as contaminated waste in the spring (Leukertová 1986).

CONCLUSION

In areas where road salt is used every winter, the stripes of vegetation along paved roads can become quite damaged. Salt may be reapplied many times during winter. High soil salinity (salt-affected soils) may be fatal for trees growing in urban areas. That is why green places in cities should be planted according to taxonomical possibilities of the tree. The paper brings a list of tree taxa useable for salty soil. Only salt-tolerant trees may grow in extremely toxic parts of urban areas. In practice, it is crucial to pay attention to the suitable type of woody species, i.e. the selection of suitable plant species, varieties, or other taxonomical levels. There must be awareness of the specifics of practical application of woody species in urban habitats that must be prepared in accordance with general principles. Desired properties of the selected trees can occur only if a proper habitat technique of planting and the following care are provided.

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